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RESEARCH REPORT

Taiwanese science students' and teachers' perceptions of the laboratory learning environments: exploring epistemological gaps

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The purpose of this study was to explore the differences between science students' and teachers' perceptions of laboratory environments. More than 1000 junior high school students and their science teachers in Taiwan were surveyed. The students showed much more dissatisfaction with approaches to laboratory activities than their teachers. They preferred a much more student-cohesive, open-ended, integrated and rule-clear laboratory environment than their teachers expected or preferred. However, the teachers sampled showed higher preferences for better equipment and material environments for laboratory work than did their students. Data from follow-up interviews with participant teachers suggested that epistemological views about science might be one of the important factors causing differences in perceptions between students and teachers of laboratory learning environments.

Introduction

In recent years, laboratory work and practical work[1] has gained renewed interest in the field of science education (for example, Leach and Paulsen 1999; Wellington 1998), although the importance of laboratory exercises on science instruction is not a new idea. Hodson (1996), for example, has elaborated on the purposes of the practical work in science education, including: (1) to help students learn science (acquiring conceptual and theoretical knowledge), (2) to help students learn about science (developing an understanding of the nature and methods of science), and (3) to enable students to do science (engaging in expertise in scientific inquiry). Students may often focus on the 'aims' of laboratory activities, but not their 'purposes'. In other words, students try to see or determine the expected results from the activities *per se*, but they do not invest much mental engagement in relating other learning experiences to laboratory work (Hart, Mulhall, Berry, and Gunstone 2000). Studies of students' laboratory activities have reported that many students gain little insight from school laboratory activities, either about the major concepts involved or the process of knowledge construction (Novak 1988). Other studies reported that students tend to follow a cookbook-type approach to experimentation, and their expressed purpose for laboratory activities is to match the truths presented in textbooks (Roth and Roychoudhury 1994; Tsai 1999; Watson, Prieto and Dillon 1995).

Possible reasons for this may come from the fact that teachers and students have different perceptions about laboratory learning environments. Science teachers may

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hope that students can engage in a wider range of learning experiences than simply verifying textbook claims, but students merely work toward the 'aims' of laboratory activities. Alternatively, students may prefer to develop a better understanding of the concepts and nature of science and scientific inquiry through laboratory work, but science teachers may not actually provide such laboratory environments or recognize these purposes. Fisher and Fraser (1983), for example, found, in an Australian sample, that students preferred a more favorable classroom environment than was being actually organized by science teachers. In the same classrooms, teachers generally perceived the environment of their classes more favorably than did students. That is, there was a gap between students' perceptions of classroom learning environments and those expressed by teachers. Fisher and Fraser probably suggested that the gap arose because of the different roles teachers and students played in the classroom environments. It is obvious that teachers and students also play different roles in the laboratory.[2] As a result, this study hypothesized that there is still a gap between science teachers' and students' perceptions toward laboratory environments.

Science educators have developed questionnaires to assess students' or teachers' perceptions about laboratory learning environments. The Science Laboratory Environment Inventory (SLEI), developed by Fraser, Giddings, and McRobbie (1995), may be the one most widely used. Several researchers have used the SLEI questionnaire to assess students' perceptions for laboratory learning environments and tried to investigate the relationships between these perceptions and their attitudinal and cognitive outcomes. For example, Wong and Fraser (1996) found that the attitudes of a group of Singapore tenth graders towards chemistry were likely to be enhanced in chemistry environments where laboratory work was linked with the theory learned in non-laboratory classes and where clear rules were provided. Henderson, Fisher, and Fraser's (2000) study revealed a similar perception–attitude relationship in Australian high school biology students. They also found that the students' perceptions about the integration of laboratory activities and theory classes were positively related to their achievement, whereas a greater degree of emphasis on rule clarity and an open-ended approach to laboratory was negatively associated with student achievement. Although students' perceptions of laboratory learning environments were associated with their attitudinal and cognitive outcomes in different ways, there were several conclusions drawn from this line of research. First, SLEI (or other learning environment instruments) could be cross-validated in a variety of contexts and used in pursuing different research and practical applications (Aldridge, Fraser, and Huang 1999; Fraser and McRobbie 1995; Fraser, McRobbie, and Giddings 1993; Kim, Fisher, and Fraser 1999). Second, a closer fit between students' perceptions of actual learning environments and those of preferred environments tended to enhance affective and cognitive outcomes (Fraser 1994, 1998). Finally, combining quantitative and qualitative methods within the same study in research on learning environments was recommended (Fraser 1998; Tobin and Fraser, 1998).

Based on this literature review, the study reported here explored a group of Taiwanese science students' and teachers' perceptions toward actual and preferred laboratory environments. The differences between students and teachers in these perceptions were also examined. Moreover, a qualitative method (i.e. interview) was also used to probe more deeply into teachers' perceptions of laboratory learning environments and their reflections on the differences in students' and teachers'

perceptions. In summary, through collecting data from a group of students and teachers in Taiwan, this study was conducted to explore the following four research questions.

1. What were students' perceptions towards actual and preferred laboratory learning environments?
2. What were teachers' perceptions towards actual and preferred laboratory learning environments?
3. What were the differences between students' and teachers' perceptions towards laboratory learning environments?
4. Based on teachers' interviews, what were their reasons for the differences in students' and teachers' perceptions?

Method

Instrument

The SLEI, developed and validated by Fraser, Giddings, and McRobbie (1995), was administered to explore teachers' and students' perceptions of laboratory activities. In its original form, the SLEI has two questionnaires: one investigates students' views about actual laboratory environments (called 'actual' questionnaire), and the other assesses students' perceptions of ideal laboratory environments (called 'preferred' questionnaire). In this study, the author changed the wording and created two additional forms for assessing teachers' perceptions of laboratory environments. Hence, a total of four questionnaires of the SLEI were used in this study. These were the student 'actual' questionnaire, the student 'preferred' questionnaire, the teacher 'actual' questionnaire and the teacher 'preferred' questionnaire. Each questionnaire was designed to monitor the following five different scales, and each scale consists of seven questions.

1. Student-Cohesiveness Scale: the extent to which students know, help, and are supportive of, one another.
2. Open-Endedness Scale: the extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation.
3. Integration Scale: the extent to which the laboratory activities are integrated with non-laboratory and theory classes.
4. Rule Clarity Scale: the extent to which behavior in the laboratory is guided by formal rules.
5. Material Environment Scale: the extent to which the laboratory equipment and materials are adequate.

Table 1 presents a sample of SLEI items for each questionnaire used in this study. The translation of the SLEI was validated by two Chinese-speaking researchers with specialization in science education. Students' and teachers' responses on the SLEI were scored as follows. For the positive-stated items, a 'very often' response was assigned 5 and an 'almost never' response was assigned a score of 1. Items stated in a reverse manner were scored in a reverse manner. Therefore, students or teachers perceiving or preferring their laboratory environments that were student-cohesive, open-ended, integrated with theory classes, and had clear rules as well as adequate materials, would have higher total scores on responding scale (full score on each scale is 35).

Table 1. Sample items in four forms of the SLEI.

Scale	*Sample items*	
	Students' version	*Teachers' version*
Student-cohesiveness	I get on well with students in this laboratory class (actual form) I would get on well with students in this laboratory class (preferred form)	My students get on well with other students in this laboratory class (actual form) My students would get on well with other students in this laboratory class (preferred form)
Open-endedness	I am allowed to go beyond the regular laboratory exercise and so some experimenting of my own (actual form) I would be allowed to go beyond the regular laboratory exercise and so some experimenting of my own (preferred form)	My students are allowed to go beyond the regular laboratory exercise and so some experimenting of their own (actual form) My students would be allowed to go beyond the regular laboratory exercise and so some experimenting of their own (preferred form)
Integration	What I do in our regular class is unrelated to my laboratory work* (actual form) What I do in our regular class would be unrelated to my laboratory work* (preferred form)	What my students do in my regular class is unrelated to their laboratory work* (actual form) What my students do in my regular class would be unrelated to their laboratory work* (preferred form)
Rule clarity	My laboratory class has clear rules to guide my activities (actual form) My laboratory class would have clear rules to guide my activities (preferred form)	My students' laboratory class has clear rules to guide their activities (actual form) My students' laboratory class would have clear rules to guide their activities (preferred form)
Material environment	The laboratory equipment which I use is in poor working order* (actual form) The laboratory equipment which I use would be in poor working order* (preferred form)	The laboratory equipment which my students use is in poor working order* (actual form) The laboratory equipment which my students use would be in poor working order* (preferred form)

* Scored in a reverse manner.

Fraser *et al.* (1995) reported that the reliability coefficients (Cronbach alpha) of the SLEI were 0.78, 0.71, 0.86, 0.74, and 0.76 on each scale for the (student) actual form, while the coefficients were 0.73, 0.70, 0.84, 0.68, and 0.73 on each scale for the (student) preferred form. The same coefficients calculated from the student sample of this study (described later) were 0.76, 0.60, 0.83, 0.75, and 0.72 on each scale for the (student) actual form, and were 0.75, 0.61, 0.87, 0.73, and 0.74 on each scale of the (student) preferred form. A pilot study evaluating the reliability of teachers' SLEI forms was conducted with 68 science teachers. The alpha coefficients for the actual form were 0.75, 0.68, 0.86, 0.77, and 0.76 on each scale, while for the preferred form they were 0.77, 0.65, 0.88, 0.75 and 0.79 on each scale.[3]

To avoid contamination of responses across two questionnaires, the administration of the two SLEI questionnaires was conducted separately: the SLEI 'actual' first, then the 'preferred' later. The period between the administration of two questionnaires was about 1–2 weeks for all subjects (including teachers and students).

Subjects

The student subjects involved in this study initially included 1211 eighth and ninth graders in Taiwan. The population was stratified into three geographic areas, Northern, Central and Southern Taiwan. Six high schools from Northern Taiwan, four schools from Central Taiwan and four schools from Southern Taiwan were selected. The school number ratio selected roughly corresponds to the actual high school number ratio across these three areas. For each selected school, one or two classes, depending on the size of the school, were chosen. The students came from 24 classes in 14 junior high schools. Although this sample could not be viewed as a national sample, the selected Taiwanese eighth and ninth graders were spread across various academic backgrounds, geographic areas and socio-economic levels, and they may, to a certain extent, represent the population of Taiwanese junior high school students as a whole. Because some students failed to complete both of the questionnaires used in this study or they had missing data in the questionnaire(s), their results were excluded from final analyses of this study. Consequently, the final sample for this study was reduced to 1012 students, 46% of them being female.

The selected students' science teachers (a total of 24) were also asked to respond to the SLEI questionnaire. So, the selected students were under the instruction of one of the selected teachers at the time of the conduct of the study. The students had been under one of the surveyed teachers' science instruction for at least 8 months. And these students had conducted at least seven sessions of laboratory under their teacher's guidance. The sample teachers had an average of 9.8 years of science teaching.

Follow-up study: interviews with some selected teachers

To explore teachers' views about laboratory learning environments more deeply and their justifications and comments on the differences between students' and teachers' perceptions towards laboratory learning environments, eight teachers were randomly selected for interview. These teachers were asked to reflect on the findings of the questionnaire study and then to give their perspectives or reasons for the findings.[4] The teachers were interviewed individually by a trained researcher. The interviews were audiotaped and were transcribed. The author analyzed the interview data by finding some similar patterns of thoughts or representative ideas as expressed by the teachers. The author translated the interview data cited in this paper. The translated data were further examined by a second independent Chinese speaker, who actually listened to the interview tapes.

Results

Actual versus preferred scores

Students' scores on the actual and preferred SLEIs are reported in table 2. A series of paired *t*-tests to compare students' mean scores on the 'actual' and

Table 2. Student perceptions of laboratory learning environments as assessed by the SLEI actual and preferred forms ($n = 1012$).

	Actual		*Preferred*		*Paired* t*-test between actual and preferred scores t-value*
Scale	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*	
Student-cohesiveness	24.27	3.55	29.23	3.55	−31.04***
Open-endedness	16.63	3.62	22.03	4.15	−30.85***
Integration	23.50	4.06	29.44	3.29	−36.18***
Rule clarity	25.50	4.06	29.04	3.16	−22.07***
Material environment	24.91	4.19	28.85	3.03	−23.50***

***$p < 0.001$.

'preferred' indicated that students' mean preferred scores were statistically significantly higher than those for the actual at the 0.001 level. That is, the sample students perceived their actual laboratory environments as less student-cohesive, less open-ended, less integrated with theory class, and with less rule clarity than they preferred. Also, they showed dissatisfaction with the material support provided by their actual laboratory environments. A similar *t*-test comparison on teachers' scores between 'actual' and 'preferred' was also conducted, and is reported in table 3. Interestingly, teachers' scores on the student-cohesive, open-ended, integration, and rule clarity scales were not statistically significantly different between 'actual' and 'preferred' at the 0.05 level. However, teachers tended to complain about the material environment in their actual school laboratories, saying they would prefer much better material support ($p < 0.001$). The studies reported by Obebukola (1992) and Soyibo (1994) also found that science teachers tended to complain the lack or inadequacy of material support in actual laboratory environments, which was related to their occupational stress in teaching science.

Table 3. Teacher perceptions of laboratory learning environments as assessed by the SLEI actual and preferred forms ($n = 24$).

	Actual		*Preferred*		*Paired* t*-test between actual and preferred scores t-value*
Scale	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*	
Student-cohesiveness	28.08	1.98	28.46	1.50	−1.44
Open-endedness	19.21	2.54	19.67	1.99	−1.66
Integration	27.25	2.17	27.54	1.44	−1.23
Rule clarity	27.63	1.81	27.88	1.42	−0.90
Material environment	23.08	2.50	32.29	1.63	−12.84***

***$p < 0.001$.

Student versus teacher scores

Table 4 presents a series of comparisons between students' and teachers' scores on each SLEI scale. For the scales of student-cohesiveness, open-endedness, integration, and rule clarity on the actual form, teachers' scores were significantly higher than students' scores. For the same scales on the preferred form, teachers' scores on the preferred form were significantly lower than those of students. Students showed less satisfaction with the approaches to actual laboratory activities than their teachers, and they expressed a preference for a much more student-cohesive, open-ended, integrated and rule-clear laboratory environment than their teachers. However, the scores on the material environment scale showed the opposite. The teachers' mean scores on the scale of the 'actual' were statistically significantly lower than those of students; the teachers' mean scores on the same scale for the 'preferred' were statistically significantly higher than those of students. This indicates the teachers being concerned for better equipment and material support in the laboratory than their students.

The results of this study implied that the sample students were concerned with the conduct of laboratory activities: student cooperation, the extent of open-endedness, the integration between laboratory and theory classes, and the rule-clarity of laboratory work. However, the sample teachers paid more attention to the material environment of the laboratory activities. These findings probably suggest that students and teachers have different foci and purposes for the laboratory activities. Furthermore, these differences may be related to their epistemological views of science.

Follow-up study: interviews with some selected teachers

As the first part of the study revealed that teachers had different perceptions of laboratory learning environments from their students, further exploration of this

Table 4. The differences between students' and teachers' perceptions toward laboratory learning environments.

	Student		*Teacher*		
Scale	*Mean*	*Standard deviation*	*Mean*	*Standard deviation*	*t-test*[a]
Student-cohesiveness (actual)	24.27	3.55	28.08	1.98	–9.10***
Open-endedness (actual)	16.63	3.62	19.21	2.54	–4.87***
Integration (actual)	23.50	4.06	27.25	2.17	–8.13***
Rule clarity (actual)	25.50	4.06	27.63	1.81	–5.42***
Material environment (actual)	24.91	4.19	23.08	2.50	3.46**
Student-cohesiveness (preferred)	29.23	3.55	28.46	1.50	2.38*
Open-endedness (preferred)	22.03	4.15	19.67	1.99	5.54***
Integration (preferred)	29.44	3.29	27.54	1.44	6.08***
Rule clarity (preferred)	29.04	3.16	27.88	1.42	3.80**
Material environment (preferred)	28.85	3.03	32.29	1.63	–9.97***

[a] Levene's test for equality of variances indicates that these two samples cannot be assumed to have statistically equal variances for each variable in the table.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

issue was made with the eight interviews. Almost all of the teachers justified their own scoring of the SLEI when asked to suggest a reason for the discrepancies between student and teacher perceptions. Their views on the differences in attitudes toward laboratory learning environments are now summarized.[5]

The student-cohesive scale. For the difference on the student-cohesiveness scale, interviewed teachers thought that they had indeed tried to create opportunities for student cooperation, but management concerns may have hindered such opportunities. For example:

> *Teacher A*: I always encourage their discussion, group work and argumentation in the lab activities. But I often found that they were talking about something unrelated to lab activities. So, I may need to keep an eye on their discussion or group work, and they may not feel very comfortable with discussion or argumentation under my close monitoring. Therefore, they may think that I could provide more favorable environments for student cooperation.
>
> *Teacher D*: I agree that ideally lab activities require a high degree of student cooperation. But, in reality, I feel hesitated to let them do this, as this causes a lot of problems of management. For example, many things that you are not expecting may happen.

These teachers' views parallel the problem of management in argumentation activities raised by Newton, Driver, and Osborne (1999). Teachers may need more knowledge or skills to be confident enough to create laboratory learning environments with a high degree of student cooperation. Moreover, some teachers' ideas about the purposes of laboratory activities may actually remove the teachers' incentive to create student cooperation opportunities.

> *Teacher B*: Although working in groups in lab activities is important, I think it is more important to follow the experimental procedures and examine how the scientific knowledge works. That is the main task of doing lab. I think I have provided enough opportunities for student cooperation, but they did not perform the experiments well. They always just talked to each other, but did not have final or certain results derived from the lab activities.
>
> *Teacher H*: I often saw that students worked together but they got nothing by the end of laboratory activities. I think that an emphasis on student cooperation may not guarantee an effective way of making the experiments be well done by students. Sometimes, a student who worked alone, but carefully followed the experimental procedures, could quickly get more accurate laboratory results.

In their talk, these teachers clearly showed how their views on the purposes of laboratory activities guided their perceptions and actual practice of school laboratory activities. Their purposes for laboratory activities were more oriented to the 'aims' of laboratory exercises, as defined by Hart *et al.* (2000). That is, for them obtaining the expected results or a series of confirmed facts was central to the organization of their own school laboratory. Such views may be related to epistemological beliefs about science. A final-form view of science or a simple positivist position on the epistemology of science may have reinforced their ideas, as well as actual behavior, when conducting and guiding school laboratory activities for students. In contrast, the survey data reported earlier showed that the Taiwanese students sampled preferred a more student supportive laboratory environment, suggesting a more social constructivist perspective for the epistemology of science. This epistemological discrepancy may contribute to an explanation of the

differences between students' and teachers' perceptions on the degree of student cooperation in actual and preferred laboratory environments.

The open-ended scale. For the differences between the mean score for students and teachers on the open-ended scale, interviewed teachers believed that students lacked knowledge and relevant skills sufficient to conduct open-ended laboratory activities. For instance:

> *Teacher B*: Students lack adequate knowledge to do that. When they get into college or even graduate schools, they will do that.
> *Teacher C*: I once tried an open-ended approach to do the lab, but it did not work well. Students always asked me what to do next. Or they asked me to just tell them the expected results or answers.
> *Teacher D*: Students need more knowledge and reasoning skills to do that. They also need to plan the details of conducting open-ended activities. I doubt whether they can do that. In regular lab, they have difficulties of following the step-by-step lab processes provided by the textbooks, so I can not imagine how they can finish the lab if it is more open-ended.

Clearly, these teachers believed that their students did not have adequate knowledge and skills to conduct open-ended inquiry; therefore, they asked their students to merely follow the codified procedures to complete the laboratory activities. Such a view may be one of the major reasons why much laboratory work at the secondary science education level is the cookbook type of instruction.

The integration scale. For the differences on the integration scale, many teachers thought that time constraints caused difficulties or problems for integration between theory and laboratory classes.

> *Teacher E*: I just did not have time to do that. The laboratory activities were completed in a rush manner. I did not have enough time to explain the relationships between the theory class and laboratory activities. And the laboratory was not often available when I needed it. As a result, there may be some mismatch between theory and lab classes.
> *Teacher D*: This is a time issue. Usually, we have just 45 minutes to finish one to two lab activities. Therefore, it is actually no time for me, in the lab, to clarify the connections between theory class and lab activities. The main task for me in the lab is to make sure that students complete the lab and get a final result. Also, they safely work with all apparatus or equipment.

Although time was the central constraining factor that teachers expressed, their epistemological views may also have influenced their thoughts on the issue of integration. For instance, Teacher H claimed that 'Theory and lab are different sides of science, so the integration between these two is not a big issue'. Again, the teachers' epistemological views of science may shape their perceptions on the nature of appropriate school laboratory activities.

The rule clarity scale. With regard to the differences on the rule clarity scale, some teachers believed that a large class size caused difficulties for providing a laboratory environment with clear rules. For instance:

> *Teacher A*: I think I have clear rules for guiding their lab activities. But I have more than forty students in a class, so it is not possible for me to promptly respond to every student's question or to carefully monitor whether they follow the rules I set.

Some interviewed teachers also pointed out a tension between providing rule-clarity and creating open-endedness. For example:

Teacher F: For me, this part of research results was strange. Students, on the one hand, ask for more freedom or open-endedness of conducting lab activities; they, however, on the other hand, ask me to set up more clear rules for them to be followed. How can I do this?

Teacher G: I try to figure out this part of findings, but can not quite understand. The rule clarity may inhibit the degree of open-endedness. So, I can not comment on this.

Practicing teachers feel a tension between the use of open-ended laboratory activities and the need for clear rules in the laboratory as requested by students. However, these two interests are not necessarily conflicting. For example, students may need clear rules in the laboratory in general, but this does not mean that teachers need to provide comprehensive guidance or rules when conducting any specific laboratory activity. It is also practically possible for science teachers to design open-ended activities with few but very clear guidelines for students.

The material environment scale. Finally, the students' and teachers' different perceptions on the material environment scale were also commented on during the teachers' interviews. As previously discussed, the findings derived from the material environment scale were different from those for the other four scales. On the material environment scale, teachers had a higher mean score on the 'preferred' than their students, while teachers tended to show more dissatisfaction with the material support offered by actual laboratory environments than their students. In interview, many teachers talked about how better material support would help students have more accurate scientific knowledge.

Teacher B: Science needs to be accurate, so the equipment and materials need to be good. Therefore, I have high standards about the material environments.

Teacher E: If we do not have better material support, students can not conduct proper experiments and then can not get a certain result that confirms the scientific knowledge. That is, they can not see what they are expecting to see. Then, what is the purpose of lab?

Teacher H: There are several reasons for requesting better material support. First, good material or equipment will facilitate the lab processes, so students will not waste their time. They will quickly get the results or products of the experiments, which is the main task of the laboratory work. Second, with the assistance of better and more precise equipment, it will help students to more accurately portray the rules of nature. Finally, if we have better material supported lab environments, students, and even me, will feel more comfortable and be more willing to do lab, as they can always get something useful or confirmed in the lab.

The Taiwanese teachers interviewed in this study believed that the laboratory was best used to get accurate, or nearly certain, results to confirm established scientific knowledge; therefore, they stressed the need of better material and equipment. Such ideas, again, imply that their epistemological views on science were more oriented to positivism and empiricism, and in turn this guided their perceptions of the aims for school laboratory activities. Research literature documents that many science teachers have positivist or empiricist views on the epistemology of science (Gallagher 1991; King 1991; Lederman 1992; Tsai 2002a). For example, Tsai (2002a) found that 21 among 37 Taiwan science teachers interviewed held a positivist-empiricist view on the nature of science. Similar findings were revealed for

teachers' views about teaching science. One-half of the student-teachers in Aguirre, Haggerty, and Linder's (1990) study viewed science teaching as 'a matter of knowledge transfer from the teacher's head and textbooks to the "empty" minds of children' (p. 388); for those teachers, the teacher was simply a presenter of the factual content of scientific knowledge. Furthermore, the role of creativity and imagination in students' science learning was not appreciated by the teachers in Aguirre *et al.*'s (1990) study. Gustafson and Rowell (1995) found that the majority of preservice teachers in their research held a *tabula rasa* view of children's minds, and they mainly viewed learning simply as gaining information. Tsai's (2002a) study on practicing teachers showed a similar finding. So perhaps it is not too surprising that many teachers in the study reported here believe that the main aim for student laboratory work is to gain scientific facts or truth. Further work is needed to survey the variety of epistemological positions held by Taiwanese students of science.

Discussion and conclusions

Through surveying more than 1000 junior high school science students in Taiwan, this study has revealed that the Taiwanese students would prefer a laboratory learning environment where they could have more student cooperation, conduct more open-ended inquiry, explore more deeply into the connections between theory and practical evidence, while having clearer rules for guidance and better material support than they actually experienced. On the other hand, their teachers did not show any gap between their perceptions of actual laboratory learning environments and those they would prefer, except on the single aspect of material support. The teachers emphasized that the actual material environment in school laboratory should be greatly improved.

The issue of control may explain the presented findings. Several teachers' comments on the first four scales of the SLEI emphasized the view that 'I tried it but it did not work', indicating teachers' control over the variables concerned. For the last scale (i.e. material environment), teachers depended on the school administration for funding, thus lacking control in this area. Students clearly had little control over any of the five scales of their laboratory environments, causing the discrepancy between actual and preferred. The issue of control may well explain the large differences between the actual and preferred learning environments for all scales of the SLEI for students, and only the last scale for teachers.

A series of comparisons for the students' and teachers' responses to the survey questionnaires also showed that students were less satisfied with the approaches to actual laboratory activities than their teachers. The students preferred more student-cohesive, open-ended, integrated and rule-clear laboratory environments than their teachers. The teachers showed stronger preferences for better equipment and material environments for laboratory work than their students.

In summary, there were basically two major gaps revealed in this study: one between students' actual and preferred, and one between students and teachers. The first gap could be explained by the issue of control, as discussed previously. Although there was no strong research evidence gathered from the students, this study hypothesized that the second gap was possibly related to epistemological views. That is, the difference on the epistemology of science between students and teachers may open a possibility for interpreting the discrepancy of perceptions for laboratory learning environments between students and teachers. Some interview

responses gathered in this study support this alternative perspective. Interviews with selected teachers revealed that those teachers focused on the aims or the products derived from the laboratory; consequently, they did not place student cooperation, or open-endedness, or integration of empirical evidence with theories as high-priority features for student learning in laboratory activities. Such a limited purpose helped explain why they claimed that material support was important as it was directly related to the positivist aims for laboratory work. So, from this study we can argue that these views were associated with the Taiwanese teachers' epistemological views on science, and these teachers showed positivist-oriented or empiricist-oriented views on the nature of science. Although this study did not gather in-depth information about students' and teachers' epistemological views about science, it believed that these could potentially be one of the major factors related to science students' and teachers' perception differences toward laboratory learning environments. This study argued these differences as 'epistemological gaps'.

Research literature in science education has showed that teachers' epistemological views of science are often considered an important factor that frames their teaching beliefs, and these views may be related to instructional practice (Abd-El-Khalick and Lederman 2000; Brickhouse 1989; Duschl, Hamilton, and Grandy 1990; Lederman 1992; Mellado 1997; Tsai 2002b). This study further suggests that the Taiwanese teachers' epistemological views of science may shape their views about the purposes of laboratory work and then influence their organization and implementation of laboratory activities.

This study has also revealed some implications for teaching or classroom practice. A potential approach of helping teachers develop their awareness about what is happening in classrooms is to make teachers comment on a comparison of students' and teachers' perceptions of learning environments. In the processes of making comments, researchers, on the one hand, can gain more insights about teachers' views about classroom practice, while teachers, on the other hand, can be encouraged to examine the strengths and weaknesses of their own teaching, which can be viewed as a way of facilitating professional development.

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Notes

1. Most 'practical work' in school science means 'laboratory-based experience'.
2. A simple definition about classroom/laboratory learning environments may be given here. Science classroom learning environments often provide teacher-guided instruction about scientific theories, whereas laboratory learning environments usually offer more student-centered hands-on activities for experimentation.
3. The alpha coefficient was consistently lower on the open-endedness scale of the Chinese-version SLEI. Taiwanese students and teachers may not fully understand the nature of open-ended laboratory learning environments, as most of them experienced relatively more close-ended laboratory activities.

4. Hence, students were not given similar interviews, as they did not have adequate background knowledge to understand the findings.
5. The interview quotations presented in this part were those being perceived as the most representative or fruitful ideas expressed by the interviewed teachers.

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